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ABSTRACT

This paper investigates the relevance of institutional prestige on career patterns of scientists at "major and minor universities," posing three questions: (1) Are scientists who are involved in the early stages of a fields development more likely to graduate from more prestigious universities? (2) Do graduates from prestigious universities pursue different career paths in terms of employment sector? and (3) Are graduates from prestigious universities who choose academic careers more likely to find employment at prestigious universities? Empirical evidence is presented from an international survey of more than 700 scientists working in the field of neural networks. The prestige of a scientist's graduate school is found to be an important indicator of the prestige of his or her academic appointment in the initial five years after graduation. Beyond five years, the effect of graduate school prestige is non-significant. This finding holds for scientists who entered the field early, as well as for those scientists who entered the field after it gained widespread legitimacy in the scientific community.

Scientists at Major and Minor Universities: Mobility along the Prestige Continuum

Given sociologists' interest in occupational and career patterns (Giddens 1989), it is not surprising that the scientific profession has received close scrutiny. Indeed, numerous aspects of the sociological dynamics of a scientist's career have been examined, but perhaps none more closely than the determinants of career advancement along the prestige continuum of research institutions—the so-called major and minor universities. How much of career success is attributable to the intrinsic quality of a scientist's research accomplishments as reflected in published work? Or, are other more "particularistic" factors at work? In other words, how important is the institutional prestige of one's doctoral degree granting university, the standing of one's thesis supervisor in the scientific community, and the socio-economic status of one's family? The origins of many of these investigations can be traced back to the Research Program in the Sociology of Science initiated at Columbia in the late 1960s.

A considerable amount of effort has been directed toward understanding the relative influence of individual productivity and accomplishment versus particularistic criteria in determining who receives academic appointments at the most prestigious departments and institutions. Although the results are sometimes contradictory (Finkelstein 1984), the empirical evidence usually confirms the importance of institutional prestige. For example, studies by Hargens and Hagstrom (1967) and Cole and Cole (1973), find that an individual's accomplishments are equally as important as one's academic background in securing a prestigious academic appointment. Crane (1965 and 1970) and Long (1978) find that the prestige factor—both in terms of one's degree granting university and one's graduate supervisor—is significantly more influential than one's research accomplishments in securing a position. In reviewing the evidence from both streams of research, Finkelstein (1984) is led

to conclude that "...at the time of initial appointment, it is much more the prestige of one's terminal degree and one's graduate sponsor than one's scholarly productivity which will lead to a good academic appointment."

Turning the question around, some investigators suggest that the prestige of an academic department may be an important contributing factor to a scientist's productivity (Hargens and Hagstrom 1967; Allison and Long 1990). Although Hargens and Hagstrom (1967) are unable to show that institutional standing influences productivity on the individual level, they do provide evidence on the aggregate level. Furthermore, Cole and Cole (1973) and Long (1978) find that institutional prestige may be nearly as important as research performance, while Crane (1965) finds institutional prestige more important than research performance in determining the amount of recognition (in terms of rewards, honors, and citation frequency) that accrues to a scientist.

In the present paper we investigate further the significance of institutional stratification within the scientific community as it relates to the inclination of scientists who are involved in pioneering a new field of research. In particular, we examine three questions: (1) Are scientists who are involved in the early stages of a fields development more likely to graduate from more prestigious universities? (2) Do graduates from prestigious universities pursue different career paths in terms of employment sector (academic, industry, government) within the scientific community? and (3) Are graduates from prestigious universities who choose academic careers more likely to find employment at prestigious universities?

Unlike earlier sociological studies, we focus specifically on scientists who enter a field early, before it is widely accepted by the rest of the scientific community. By "early entrants," we mean those scientists who initiate and continue working in a field before it is widely recognized as significant, or perhaps even legitimate by their peers. Empirical evidence suggests that such scientists, statistically speaking, are relatively rare: although the probability

of a scientist remaining with a given field of research increases the longer he or she stays with it, the likelihood a scientist will persist more than a few years is fairly low (Rappa and Garud 1992). Despite their scarcity, the scientists who enter a field early are essentially the catalysts behind change in science. By virtue of their unconventional problem choices and unrelenting determination, they may ultimately lead the way in creating a new research specialty. While we have isolated early entrants for in-depth examination, in doing so we nonetheless do not mean to underestimate the significance of contributions to a field made by scientists who follow afterward.

Institutional stratification within the scientific community raises an interesting question with respect to scientists who enter a field early. It may very well be that the relative stature of a university has some relevance in the pioneering behavior of its faculty and students—what might be called the "backwater hypothesis." On the one hand, prestigious research universities may have the resources that would enable those scientists who are inclined to take chances to more readily explore new fields. On the other hand, the prominence of such institutions may tend to reinforce among their scientists a more cautious attitude toward doing science that extends rather than challenges conventional thinking. It is not uncommon that in the early stages of emergence, radically new streams of research can lack legitimacy within the scientific community. Unable to convince their mainstream colleagues, some scientists may seek haven at lesser known institutions in order to pursue their unconventional research. In the same vein, one might extend the argument to ask whether students who pursue pioneering research agendas are any more or less likely to obtain positions at prestigious universities upon graduation.

The case of "cold fusion" research provides a recent illustration (Mallove 1991). Setting aside the issue of whether or not cold fusion has merit, the events surrounding this discovery exhibit how institutional prestige may play a role in the way scientists approach

unconventional research. The remarkable claims of cold fusion and the subsequent efforts to confirm it, quickly degenerated into a major scientific controversy pitting those scientists who found evidence of its effect against those who saw it as spurious—if not scandalous. Through the course of the debate, undercurrents of elitism emerged among some scientists. The suggestion was that reports which confirmed cold fusion were more likely to come from lesser known institutions, while unconfirmed reports came from, as one scientist put it, "schools not known for their football team." What is most interesting is that such perceptions did not actually fit the reality. A close examination of the record shows little if any correlation between institutional prestige and the propensity to confirm cold fusion research. Nevertheless scientists are mindful of perceptions. Cold fusion is a cautionary tale that underscores how issues of institutional prestige can become muddled in scientific debates.

THE NEURAL NETWORK RESEARCH COMMUNITY

In order to examine these questions empirically, we take as the basis of this paper a recent international survey we conducted of more than seven-hundred scientists working on the development of neural networks. A neural network is a type of information processing system that is inspired by models of the human brain. By using a biological model in its design, a neural network system has certain features that make it unique in form and function from conventional computers. For example, a neural network is not programmed in the usual sense, but rather it is trained with data. This implies that the computational performance of a neural network improves with experience: as it processes more and more information in performing a task, it becomes increasingly more accurate in its response.

Another distinctive feature of a neural network is its degree of parallelism in processing a task. Unlike a normal computer with a single or small number of sophisticated central processing units, a neural network has a very large number of simple processing elements that

operate simultaneously on a computational problem. These features allow it to perform certain tasks that otherwise might be very difficult using existing computer technology. Neural networks are also referred to as connectionist systems, adaptive systems, or neurocomputers (see DARPA 1988).

Neural networks have a considerable history of development, stretching back to theoretical explanations of the brain and cognitive processes proposed during the 1940s. In the early years, scientists formulated and elaborated basic models of neural computing that they then used to explore phenomena such as adaptive stimulus-response relations in random networks. By the 1960s there were several efforts to implement neural networks, the most notable being the single-layer "perceptron." Among neural network scientists the perceptron was considered a watershed, but at the same time it served as a lightning rod for criticism from scientists more interested in the burgeoning field of artificial intelligence. The idea of neural networks, as exemplified by the perceptron, quickly became seen as almost antithetical to the symbolic reasoning principles of artificial intelligence. Critical analysis of the perceptron led some highly respected AI scientists to proclaim that the concept was fundamentally flawed, and as such, inappropriate for scientists to waste much effort on. By casting doubt as to its legitimacy, antagonists of neural networks may have effectively dissuaded other scientists from entering the field in larger numbers (Minsky and Papert 1988; Papert 1988).

The controversy surrounding neural networks notwithstanding, work continued during the early 1970s with perhaps no more than a few hundred scientists worldwide in the field. Undeterred in their belief of the potential of neural networks, their persistence over the next decade eventually paid-off. By the 1980s, neural networks began to be viewed in a new light by scientists in a variety of disciplines, such that the field soon achieved a position of legitimacy within the scientific community. A professional society for neural network

scientists was formed, specialized journals and books were published, and the first in a series of international conferences were held.

While it is difficult to explain exactly why perceptions of the field changed so dramatically, at least four important technical events can be discerned: (1) the evolution of the single-layer perceptron into a multi-layer system; (2) the rapid development of related technologies that enabled scientists to develop, simulate, and diagnose neural networks of greater sophistication; (3) significant progress in theoretical understanding of neuro-biological processes; and (4) the contributions of scientists pursuing the idea of parallel distributed processing, the so-called PDP-group. In light of these developments, as well as others, interest in the field became widespread, such that the number of scientists working on neural networks expanded rapidly. By the end of the decade the size of the field swelled in membership from a few hundred to several thousand scientists worldwide.

The evolution of the neural network research community is not unusual and may even be typical of emerging fields in some of its sociological characteristics. From our research, we have found that it is fairly common for new fields to lack widespread acceptance for long periods, sometimes attracting controversy, other times simply being ignored by scientists. But when they do catch on, fields tend to grow rapidly. This pattern has occurred, to greater or lesser extent, in several fields we have examined—including one field that ultimately faltered. Given the recent experience within the field of neural networks, this case presents us with an opportunity to examine in great detail the experience of pioneering scientists relative to large numbers of scientists who follow in their footsteps.

METHOD AND DATA

Through an analysis of published sources, including books, journal articles, and conference proceedings for the two-year period from 1988 to 1989, we identified more than

3,000 scientists worldwide working on the subject of neural networks. From this material, we were able to determine the exact address for each of 2,037 scientists in thirty-five different countries. Given the scope of the research community, a survey questionnaire was determined to be the most appropriate method of investigation. A twelve-page questionnaire in English was sent to scientists inquiring about (a) their neural network activities, (b) their decision to begin working on neural networks, (c) factors that might lead them to cease their neural network research in favor of another problem area, (d) their interaction with the rest of the neural network research community, and (e) their demographic characteristics. The questionnaire was pretested in the United States. Additional tests were conducted in Europe to reduce potential interpretational difficulties arising among those respondents for whom English is a second language.

Since thirty-seven scientists had more than one address during the time period considered, a total of 2,074 questionnaires were mailed in February 1990. After the third week of data collection, we mailed a follow-up letter and posted e-mail messages on computer bulletin boards to alert neural network scientists of the survey. Of the 2,074 questionnaires, 162 were returned as undelivered by the post office. None of the thirty-seven scientists with more than one address were among in the undelivered questionnaires. At the completion of the data collection period approximately ninety days later, 720 of the 1,875 questionnaires presumed to be delivered were completed and returned, yielding a final response rate of 38.4 percent. Some of the factors that may have affected the response rate include: the length of the questionnaire, the global scope of the survey, and the institutional mobility of scientists.

The representativeness of the respondent sample was evaluated in three ways: by contrasting respondents with the original survey population in terms of their geographic distribution, their institutional distribution, and the distribution of their disciplinary

backgrounds. In each instance, there is no statistically significant difference between the respondent sample and the survey population.

INSTITUTIONAL PRESTIGE

We rank-order the universities in our survey database according to an index of institutional prestige. We use as the basis of our index the citation and publication data on U.S. universities, which was compiled by Small (1990) and his colleagues at the Institute for Scientific Information and recently used by the Office of Technology Assessment (1991) to rank U.S. universities. Citation impacts scores (i.e., the ratio of total citations to total papers published[1]) have been implemented in a variety of studies to measure the relative eminence of a scientist (Myers 1970) and prestige of academic departments (Roche and Smith 1978), a laboratory's research performance (Mullins 1987; Narin 1987), and the competitive stature of a country's scientific community (Narin and Frame 1989).

In our study the citation impact score of publications for each university over the fifteen-year period between 1973 and 1988 is used as a (continuous) proximate measure of institutional prestige. An examination of the rank-order of the top-100 U.S. research universities suggests that citation impact scores have good face validity as a measure of institutional prestige (see Small 1990). Nonetheless, it is important to recognize that this measure pertains to the university as a whole and not to the prestige of individual departments, which can vary widely in a given university. The score also does not reflect institutional prestige that may arise from criteria other than research performance such as excellence in teaching, for example.

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[1] The continuous prestige index is computed as follows (with P_i= prestige score for academic institution i):

$$P_i = \frac{\left(\sum_{1973}^{1988} \text{citations}\right)_i}{\left(\sum_{1973}^{1988} \text{publications}\right)_i}$$

Because the validity of making international comparisons with citation impact scores is not well-established, the present analysis includes only those respondents who graduated from U.S. academic institutions. Excluding non-U.S. universities reduces the original sample from 720 to 373 respondents, the large majority of whom (N = 348) are currently employed within the U.S. Most of the twenty-five respondents who were educated in the U.S. but no longer reside there, left the country upon graduation. At the time the survey was conducted, twenty-two of them held posts at foreign universities. For the 348 respondents who were educated and reside in the U.S., 207 (59-percent) are employed in academic labs, 103 (30-percent) reside in industrial laboratories, and 38 respondents (11-percent) are employed in non-academic, not-for-profit institutions—primarily government laboratories. The sector distribution of respondents does not differ significantly from that of the original sample (χ^2=3.35, n.s.).

For each of the 373 U.S.-educated respondents in the sample we compute a citation impact score for their *graduate* school. There are a total of 104 universities represented in the sample. Using the ISI data, we also compute an institutional prestige measure for each respondent's *current* academic employer (in all cases but two). The respondents hold appointments at 86 different U.S. universities. We do not calculate institutional prestige scores for industrial employers. Although industry data exist, its adequacy as a measure of prestige for industrial labs requires closer inspection, which is beyond the scope of the present study. As a result, there is a total of 205 respondents for whom we calculate prestige measures both for their graduate school and for their current academic employer.

The continuous measure of prestige is used to create an ordinal variable. The 125 universities (graduate schools and current employers) are divided into 20-percent intervals, thereby creating five equal ranks. The 25 institutions in the top-20 percent interval have citation impact scores in excess of 16.31. The 20-to-40 percent interval have scores ranging

from 13.55 to 16.17. The 40-to-60 percent interval have scores between 10.64 and 13.48. The 60-to-80 percent interval have scores between 8.10 to 10.52. The 25 remaining institutions have citation impact scores below 8.10.

The distribution of respondents by prestige of graduate school and by prestige of current academic employer are shown in Table 1. Both sets of academic institutions considered in this table have a modus in the top-20 category. Inspection of the median values for both distributions further indicates that the majority of respondents are in the top categories as far as institutional prestige is concerned.

— Insert Table 1 about here —

SCIENTISTS AT MAJOR AND MINOR UNIVERSITIES AND EARLY ENTRY TO THE FIELD

According to a classification scheme previously developed and reported, we classify respondents as early or late entrants depending upon when they enter the field. In short, early entrants are those scientists who begin research in a field before it obtains widespread legitimacy within the scientific community. After a careful historical and statistical analysis of the field of neural network, examining many different factors and testing for sensitivity, we divided the sample into early and late entrants using 1984 as the transitional year. There is nothing inherently significant about this year, in particular. Indeed, we could have chosen any year between 1980 and 1984. We tested the sensitivity of selecting 1984 as the cut-off year by performing a discriminant analysis on the core survey items. The results indicate that the categorization scheme is robust.

By demarcating the sample into two periods, we do not mean to imply that the field's transition to legitimacy was instantaneous; we do so simply to preserve cases for the statistical analysis. Nonetheless, something—or, perhaps, many things—unmistakably happened in the

early 1980s that transformed neural networks from a curiosity and the object of skepticism to a major interdisciplinary stream of research. An examination of the scientific literature and discussions with neural network scientists also supports our selection of 1984. Prior to 1980 there were no more than a few hundred neural network scientists worldwide; after 1985, the neural network community grew many fold, such that today there are several thousand scientists working in the field.

Table 2 shows the distribution of respondents by rank (graduate school and current employer) according to our classification of early and late entry. Among the 373 respondents present in the sample, 76 (21-percent) entered the field of neural networks prior to 1984. The 287 respondents who entered the field since 1984 (79-percent). Ten respondents did not specify the year they started their neural network activities. No statistically significant differences are apparent between early and late entrants as far as the distributions of graduate school rankings and current academic institution rankings are concerned.

— Insert Table 2 about here —

We further classify respondents according to their educational status at the time they began neural network research: that is, pre- or post-receipt of their highest academic degree. For simplicity, we will refer to pre- and post-degree respondents as "students" and "graduates," respectively. In the present sample, 162 respondents (45-percent) are classified as students when they entered the field; 169 respondents (47-percent) are classified as graduates. In order to avoid ambiguities, we omit 29 respondents (8-percent) who obtained their highest degree in the year they entered the field of neural networks. Sixty-six percent of the early entrants were students (principally pursuing doctoral degrees) when initiating work in neural networks, in comparison to about 44-percent of late entrants. Table 3 shows the distribution of respondents by rank of graduate school, comparing early and late entrants according to their educational status when entering the field.

— Insert Table 3 about here —

Mann-Whitney tests, comparing the distribution of students and graduates within each group, indicate significant differences both among early and late entrants. About 48-percent of early entrants who entered the field prior to receiving their highest degree have graduated from a top-ranked university. This is not true for early entrants who entered the field once they obtained their highest degree ($p<0.05$). As far as late entrants are concerned, however, slightly less than 40-percent of the respondents who entered the field after graduation obtained their highest degree from a top-ranked university. About 16-percent of late entrants who entered prior to graduation hold degrees from institutions with the lowest rank ($p<0.05$).

It is interesting to note that the lower-ranked institutions (fourth-20 and fifth-20) become visible in the sample only after the field attains widespread legitimacy. A further analysis of the students among late entrants shows that, of the 15 respondents in the fourth-20 rank, 80-percent were students at the time of the survey. For the 18 respondents in to the fifth-20 rank, 56-percent were in the process of obtaining their highest degree at the time of the survey.

The disproportionate representation of students among early entrants at top-ranked universities in the respondent sample may also be the consequence of time-dependent processes. Given the time span of the field's emergence, scientists (regardless of their educational status at the time they began neural networks research) who graduated from universities of lesser rank during the early years may have moved-on to other research agendas. As a consequence, their lack of persistence in the field may have led to their exclusion from the survey population as early entrants. If this is the case, then top-ranked universities produce scientists with a higher commitment to their chosen research agenda

than lower-ranked institutions. But to be certain, we must test this hypothesis using a longitudinal research design, which is now being conducted.

Additional Mann-Whitney tests comparing early and late entrant graduates do not yield a statistically significant difference ($z=0.63$, n.s.). However, when we compare early and late entrant students, we find the difference to be highly significant ($z=3.08$, $p<0.01$): earl entrant student are more likely to graduate from top-ranked universities than are students who are late entrants.

A final word of caution is warranted. The disproportionate representation of early entrant students relative to graduates may be another consequence of time-dependent processes. Since graduate early entrants are, on average, about ten years older than student early entrants when they enter the field, their numbers (and hence representation in the sample population) are likely to be diminished to some degree by retirement. As a result, graduate who entered early may be slightly underrepresented in the respondent sample. Nonetheless, the fairly large disparity in representation between students and graduates would be difficult to explain by retirement alone.

WHAT HAPPENS AFTER GRADUATION?

Now that we have an insight into the graduate school distributions of early and late entrants, the next question is: What happens to respondents after they receive their highest degree? Do they pursue academic careers or do they seek employment in another sector of the scientific community? Furthermore, what is the nature of mobility along the continuum of institutional prestige, and how does mobility relate to the conduct of pioneering research? Specifically, what are the consequences of entering a field early in terms of a scientist's ability to secure an initial appointment after graduation?

We use the ordinal prestige rankings to investigate the inter-sector mobility of graduates from major and minor universities. In order to facilitate the analysis, we collapse respondents into three categories: those who graduated from (1) top-20 institutions, (2) universities in the second-20 percent interval, and (3) all other graduate schools. This aggregation is necessary to alleviate the potential for cell size problems in some of the non-parametric statistical tests used in this section. Furthermore, to avoid any ambiguity, respondents in the process of obtaining their highest degree or graduating at the time of the survey are omitted from the analysis.

As demonstrated in Table 4, no statistically significant differences are found with respect to the respondents' current sector of employment: graduates from major universities show a sectoral distribution pattern which is highly similar to that of their colleagues from minor universities. Furthermore, for each sector of employment, the respondent distributions which are based on the rank of their graduate school are not significantly different.

— Insert Table 4 about here —

Introducing the early/late entrant dichotomy does not modify the conclusions discussed in Table 4. Detailed contingency table analyses do not allow us to reject the null-hypothesis of independence between graduate school prestige and current sector of employment for both early and late entrants. This result was further confirmed by fitting an unsaturated log linear model to the data using the three-way sectoral classification, the three-way ordinal prestige classification, and the dichotomous early/late entry classification as parameters. If the variables are independent, they can be represented by a log-linear model that does not have any interaction terms (Knoke and Burke 1980). Thus, in our case the independence model looks as follows:

$$\log \widehat{F}_{ijk} = \mu + \hat{\lambda}_i^{entry} + \hat{\lambda}_j^{sector} + \hat{\lambda}_k^{prestige} \qquad \text{(EQ. 1)}$$

where $\widehat{F}_{ijk}$ is the expected frequency in the (i,j,k)th cell based on the model. Two iterations are required for convergence. The standardized residuals are well below ±1.96, indicating no substantial discrepancies between the model and the data. Furthermore, inspection of the normal probability plot does not show the distribution of the standardized residuals to deviate substantially from a normal distribution. The likelihood-ratio χ^2 statistic for the independence model is 15.66 (d.f.=12, p=0.21). The Pearson χ^2 statistic is 13.55 (d.f.=12, p=0.33). The results do not allow us to reject the independence model and thus confirm the contingency table analyses.

Due to empty cells, we can not include the educational status of the respondent at the time of entry as a fourth parameter in the independence model. We do, however, repeat the analysis with the three-way sector classification, the three-way ordinal prestige classification, and the dichotomous student/graduate classification as parameters in an unsaturated independence model similar to Equation 1. The result is comparable to the one obtained with the previous model: likelihood-ratio χ^2=15.42 (d.f.=12, p=0.22) and Pearson χ^2=13.15 (d.f.=12, p=0.36). Once again, we are unable to reject the independence model. Inspection of the standardized residuals reveal no problems related to normality. This result is to be expected from detailed contingency table analyses: the sectoral patterns shown in Table 4 remain consistent when studying respondents who enter the field as students versus respondents who enter after graduation.

To conclude, the prestige of one's graduate school does not appear to be an important determinant of a respondent's current sector of employment. Whether a respondent is a graduate from a top-ranked university or not, or whether a respondent is an early entrant or not, does not lead to significantly different employment sector patterns upon graduation. For instance, the empirical evidence presented here does not suggest that a graduate from a top-ranked institution is more likely to stay in academia than a graduate from an institution of

lesser rank. This result holds for early as well as late entrants. These findings, of course, warrant further scrutiny. More specifically, we are interested to see what happened to those respondents who stayed in academia: what is their mobility along the prestige continuum?

MOBILITY ALONG THE PRESTIGE CONTINUUM

In this section we examine the relative difference in prestige ranking for a respondent's graduate school and his or her employer upon graduation. We limit the analysis to the 205 respondents who hold academic appointments. The Pearson correlation coefficient between the prestige of one's graduate school and the prestige of one's current academic employer is 0.56 ($p<0.001$; $N=205$). This finding reaffirms prior sociological research on the relationship between the prestige of one's graduate institution and the chance of becoming employed at a prestigious academic institution. After adjusting the data by removing students and recent graduates, the remaining sample has a 0.40 ($p<0.001$; $N=139$) correlation between graduate school prestige and the prestige of current academic affiliation.

In order to study mobility along the continuum of institutional prestige in greater detail, we compute the change in institutional prestige between one's current academic employer and his or her graduate school for each respondent using the continuous prestige measure (see Table 5). In comparison to late entrants, the data indicate that early entrants realize a much greater decrease in their institutional prestige ranking (a marginal mean of –3.37).

— Insert Table 5 about here —

In order to understand the possible meaning of this result, we employ a two-factor analysis of co-variance with the continuous differential prestige variable as a dependent variable and the early/late and student/graduate dichotomies as independent variables (see Table 6). Our choice of independent variables follows from the previous analysis. The time

elapsed since the respondent's graduation (i.e., years of professional experience[2]) is used as a covariate. (It would be preferable to use the respondent's year of initial employment at his current academic affiliation to compute this covariate. Although we inquired in the survey about the date of initial employment, there are a large number of missing values thereby yielding cell sizes that are too small for statistical analysis. As a consequence, we use professional experience at the time of the survey as a proximate covariate.) By this definition, it is assumed that students have not yet accumulated professional experience.

— Insert Table 6 about here —

As shown in Tables 6, changes in institutional prestige between graduate school and current academic employer can largely be explained as a function of the time elapsed since obtaining one's highest degree. The raw regression coefficient for the covariate is –0.155 (p=0.005), which suggests a decrease in institutional prestige as the respondent's professional experience increases. The respondent's educational status when entering the field of neural networks does not exert any main effects, nor do there appear to be any statistically significant interaction effects. In comparison to late entrants, scientists who entered the field early are more likely to be employed at institutions that are less prestigious than their graduate schools were. However, when controlling for professional experience, the first-order difference is not significant. Thus, the early/late entry dichotomy does not help us to explain differences in institutional prestige: early and late entrants to the field experience similar decreases in institutional prestige as they progress in their career.

Repeating the two-factor ANCOVA with the respondents' age as a covariate yields results similar to that reported in Table 6. The independent variables do not show any statistically

[2] Professional experience is defined as the time elapsed since the receipt of one's highest degree. Professional experience at entry is then measured as the number of years between the receipt of one's highest degree and the year he entered the field of neural networks. Professional experience at the moment of the survey is measured as the number of years elapsed since the receipt of one's highest degree in the year the survey took place, i.e. 1990.

significant interaction effects nor main effects. The age covariate is statistically significant ($p=0.004$) and has a negative regression coefficient (-0.165). The correlation between professional experience and age is 0.89 ($p<0.001$).

The relationship between graduate school and the prestige of one's current employer is further investigated by classifying respondents into four cohorts based on professional experience: 1-to-5 years, 6-to-10 years, 11-to-15 years, and more than 15 years. This enables us to test the relationship between prestige of graduate school and prestige of current employer within each cohort with a regression model. The prestige of the respondent's current academic affiliation is the dependent variable. A dummy variable is included in the model to test the relevance of a respondent's status as an early (value=1) or late entrant (value=0). Admittedly, as with the previous ANCOVA, it is preferable to use the respondent's initial year of employment at the current academic affiliation to compute the covariate. Cohorts could then be based on the time between a respondent's graduation and first year of employment at the current academic employer. Instead we use professional experience at the time of the survey as a proximate covariate.

Table 7 shows that only the model for the first cohort is statistically significant: institutional prestige of graduate school is highly significant for respondents within 1-to-5 years of graduation. Beyond five years, graduate school prestige is no longer a good predictor of the institutional prestige of a respondent's current employer. Although the regression coefficient of the early/late entrant dummy variable is always negative, it never attains statistical significance, thus confirming the previous ANCOVA results.

— Insert Table 7 about here —

DISCUSSION AND CONCLUSION

The relative prestige of a university within the scientific community is an important consideration when it comes to choosing a doctoral program. While a number of factors may enter into their decision, the reputation of a university is likely to weigh heavily on the minds of prospective doctoral students. With institutional prestige comes access to an abundance of human and physical resources necessary to conduct leading-edge research. Moreover, the centrality of prestigious universities provides a level of visibility to scientists within the scientific community that can be instrumental to establishing the legitimacy of a research agenda. Institutions also benefit from their relative standing precisely because they are able to attract highly qualified students, who in turn reinforce the overall research capabilities of a university. One need only listen momentarily to a university dean or provost before realizing the weight of a school's ranking among its peer institutions.

Clearly, institutional prestige matters—to students, to faculty and to university administrators. Nonetheless, the benefits of prestige may come with a cost in terms of scientific innovation, since the next most important objective to having a good reputation is maintaining one. However, when it comes to pioneering new fields of science, it is often necessary for scientists to take career risks: to risk that their unconventional ideas will not bear fruit, that no other scientists will follow their lead, or that their efforts will be seen as misguided by colleagues. Does the pressure of protecting an institution's standing reduce the incentives to scientists for pursuing unconventional research direction? Or, conversely, among lesser known institutions, does the desire to attain a higher standing lead scientists to take risks that others might not otherwise consider?

In the case of neural network scientists the evidence is mixed. Comparing the distribution of respondents across the prestige continuum we find no significant difference between scientists who entered the field early and those who followed them. However, when

we divide the sample according to whether or not the respondent initiated work in the field of neural networks prior to receiving his or her highest degree, we find some interesting differences. First, among early entrants, respondents who are students when they started neural network research do their graduate work at more prestigious universities in comparison to those who initiated neural network research after receiving their highest degree. Second, among respondents who are students when entering the field of neural networks, early entrants do their graduate work at more prestigious universities than do late entrants. Thus, we find pioneering behavior to be most prevalent among respondents who were students (at the time they started neural networks research) at the more highly ranked universities.

Examining the career progress of respondents, we find that over time scientists tend to move from relatively more prestigious universities to less prestigious universities. This pattern occurs regardless of whether a respondent is an early or late entrant or whether he or she is a student when entering the field of neural networks. The relevance of such a finding can be seen in the premium that prospective doctoral students place on starting their career at a highly ranked graduate school. When comparing early and late entrants, we find that scientists who entered the field early are less likely to receive an appointment at an institution matching the prestige of their graduate school. However, when controlling for professional experience the difference is not statistically significant .

If institutional prestige matters at all, it appears to matter most early-on in a scientist's career. When we examine the data by cohorts we find that graduate school prestige is a significant determinant of the prestige of a respondent's subsequent academic appointment during the first years of a scientist's career. Beyond five years, graduate school prestige is no longer significant. The cohort model thus supports Finkelstein's (1984) contention that graduate school prestige matters most *during the first years of an academic career.* Whether or

not a respondent is an early entrant, is of no consequence in explaining the prestige of his or her current university.

Thus, the neural network community does not provide evidence to support the "backwater" hypothesis. Instead, we find that early entrants who persisted in neural network come from laboratories at the more prestigious graduate schools. Nonetheless, what is interesting is that early entrants are more likely to be students as opposed to scientists who already hold their doctorate. In light of this finding we must consider the question of whether it is the length of a scientist's professional experience rather than institutional prestige that has a bearing on pioneering behavior.

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UNIVERSITY RANK	GRADUATE SCHOOL		CURRENT INSTITUTION	
	N	%	N	%
First-20 percent	131	35.1	61	29.8
Second-20 percent	108	29.0	56	27.3
Third-20 percent	69	18.5	33	16.1
Fourth-20 percent	41	11.0	31	15.1
Fifth-20 percent	24	6.4	24	11.7

Table 1: *Distribution of respondents in terms of the ranking of their graduate school and in terms of the ranking of their current academic employer (median)*

UNIVERSITY RANK	GRADUATE SCHOOL				CURRENT INSTITUTION			
	EARLY ENTRANT		LATE ENTRANT		EARLY ENTRANT		LATE ENTRANT	
	N	%	N	%	N	%	N	%
First-20 percent	31	40.8	96	33.5	10	23.3	51	32.5
Second-20 percent	<u>21</u>	<u>27.6</u>	<u>85</u>	<u>29.6</u>	<u>12</u>	<u>27.9</u>	<u>42</u>	<u>26.8</u>
Third-20 percent	17	22.4	51	17.8	9	20.9	24	15.3
Fourth-20 percent	6	7.9	34	11.8	9	20.9	22	14.0
Fifth-20 percent	1	1.3	21	7.3	3	7.0	18	11.5
Mann-Whitney test	z=1.57, n.s.				z=0.87, n.s.			

<u>Table 2:</u> *Institutional rank-order distributions for early and late entrants (<u>median</u>)*

	EARLY ENTRANTS				LATE ENTRANTS			
	STUDENT		GRADUATE		STUDENT		GRADUATE	
RANK GRADUATE SCHOOL	N	%	N	%	N	%	N	%
First-20 percent	22	47.8	7	29.2	33	28.4	54	37.2
Second-20 percent	<u>14</u>	<u>30.4</u>	<u>7</u>	<u>29.2</u>	<u>39</u>	<u>33.6</u>	<u>37</u>	<u>25.5</u>
Third-20 percent	10	21.7	6	25.0	11	9.5	33	22.8
Fourth-20 percent	0	0.0	4	16.7	15	12.9	18	12.4
Fifth-20 percent	0	0.0	0	0.0	18	15.5	3	2.1
Mann-Whitney test	z=2.07, p<0.05				z=1.83, p<0.05			

<u>Table 3:</u> *Institutional rank-order distributions for early and late entrants according to their educational status at the time they entered the field (<u>median</u>)*

Note: STUDENT = respondents initiating neural networks <u>prior to</u> receiving highest degree.
GRADUATE = respondents initiating neural networks <u>after</u> receiving highest degree.

RANK GRADUATE SCHOOL	CURRENT SECTOR OF EMPLOYMENT		
	ACADEMIA	INDUSTRY	GOVERNMENT
First-20	64	33	13
Second-20	47	24	3
Others	51	32	14

Table 4: *Prestige of graduate school versus sector of current employment (N=281)*

Note: Pearson χ^2=5.50, d.f.=4; n.s.; Kruskal-Wallis one-way ANOVA: χ^2=0.61, n.s.

	EARLY ENTRANTS	LATE ENTRANTS	MARGINAL MEANS
STUDENT	– 3.03 (N=24)	0.77 (N=19)	– 1.35
GRADUATE	– 3.98 (N=13)	– 0.96 (N=64)	– 1.47
MARGINAL MEANS	– 3.37	– 0.56	– 1.43

Table 5: *Average changes in prestige of academic affiliation for early and late entrants according to their educational status at the time they entered the field*

Note: prestige change is calculated as: prestige of current employer minus graduate school prestige.

VARIABLES IN THE ANALYSIS	D.F.	F	P
professional experience *(covariate)*	1	8.05	0.005
early/late entrant *(independent variable)*	1	3.41	n.s.
student/graduate *(independent variable)*	1	0.09	n.s.
interaction *(between independent variables)*	1	0.08	n.s.

Table 6: *Two-factor ANCOVA on changes in prestige of academic affiliation for early and late entrants according to their educational status at the time of entry*

Note: analysis omits respondents without professional experience at the time of the survey (i.e. students).

Professional experience	CONSTANT	PRESTIGE OF GRAD. SCHOOL	EARLY/LATE ENTRANT	ADJ. R^2	F
1-to-5 years (N=49)	5.85** (1.9)	0.65*** (0.1)	−1.86 (1.5)	0.39	15.8***
6-to-10 years (N=30)	10.54** (3.2)	0.17 (0.2)	−0.21 (2.1)	0.00	0.33
11-to-15 years (N=23)	7.96* (3.5)	0.42 (0.2)	−0.28 (2.0)	0.07	1.89
more than 15 years (N=28)	7.63* (3.6)	0.40 (0.2)	−2.20 (1.8)	0.07	2.0

TABLE 7: *Regressions for current affiliation prestige (D.V.)*

Note: * $p<.05$
** $p<.01$
*** $p<.001$

(standard errors in parentheses)

Date Due